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Thermal Power Systems Small Power Systems Applications Project

Siting Issues for Solar Thermal Power Plants With Small Community Applications

H. J. Holbeck
S. J. Ireland



July 20, 1978

Prepared for
Department of Energy
by

Jet Propulsion Laboratory
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ABSTRACT

Technologies for solar thermal plants are being developed to provide energy alternatives for the future. Implementation of these plants requires consideration of siting issues as well as power system technology. While many conventional siting considerations are applicable, there is also a set of unique siting issues for solar thermal plants. Early experimental plants will have special siting considerations.

This report considers the siting issues associated with small, dispersed solar thermal power plants in the 1- to 10-MWe power range for utility/small community applications. Some specific requirements refer to the first 1-MWe engineering experiment for the Small Power Systems applications (SPSA) Project.

The first two sections of the report provide background for the subsequent issue discussions. The introductory section describes the SPSA Project and the requirements for the first engineering experiment and gives the objectives and scope for the report as a whole. A brief overview of solar thermal technologies is followed by a discussion of some technology options.

The siting issues themselves are discussed in the remainder of the report in three categories: (1) system resource requirements, (2) environmental effects on the system, and (3) potential impact of the plant on the environment. Within these categories, specific issues are discussed in a qualitative manner. Examples of limiting factors for some issues are taken from studies of other solar systems. Important siting issues are summarized in the last section of the report.

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I. INTRODUCTION

A. BACKGROUND

Technologies for solar thermal power plants are being developed on an accelerated basis to provide alternatives for future energy needs. Use of these technologies requires suitable sites. Acquisition of the most desirable sites will increasingly be in competition with other potential uses as population and industrial growth expands. There is also an increasing public and governmental awareness of alternative land uses and environmental impacts.

Some of the siting issues for a solar thermal power plant are common to a wide variety of development projects while others are unique to the requirements and effects of this new technology. All developments must consider physical and engineering characteristics, such as topography, soils, geology, meteorology, and construction costs. Another important consideration is the availability of the prospective site from the perspective of local zoning ordinances and regulatory agency requirements. In addition, the environmental impact of development projects on both the natural environment and the socio-economic environment has come to the forefront since the passage of the National Environmental Policy Act (NEPA).

The siting of conventional electrical generation facilities, both nuclear and fossil fueled, is strongly affected by considerations of safety, pollution, and aesthetics. Solar thermal-electric power plants minimize some of these effects while introducing new siting limitations of their own. The availability of adequate insolation is an obvious siting factor as is the availability of adequate land. Small, dispersed solar facilities should be close to the power demand to minimize transmission costs. Early, experimental plants will have additional siting considerations to satisfy experimental objectives.

B. PROJECT DESCRIPTION

1. General Project Background

The Small Power Systems Applications (SPSA) Project is an element of the Thermal Power Systems Office of the Department of Energy (DOE). The overall goal of the SPSA Project is to promote the commercialization of solar thermal power systems for a variety of electric power applications in the one- to ten-megawatt (1- to 10-MWe) power range. The project technical approach is centered around engineering system experiments and demonstrations of appropriate technologies and applications.

2. First Engineering Experiment System Development

The first engineering experiment, with a capacity of approximately 1 MWe, will be designed and constructed in a three-phase program. The schedule for the system development is shown in Figure 1. Three technology approaches are being considered in the systems definition phase. (Technology options for solar thermal power plants are described in Section II.)

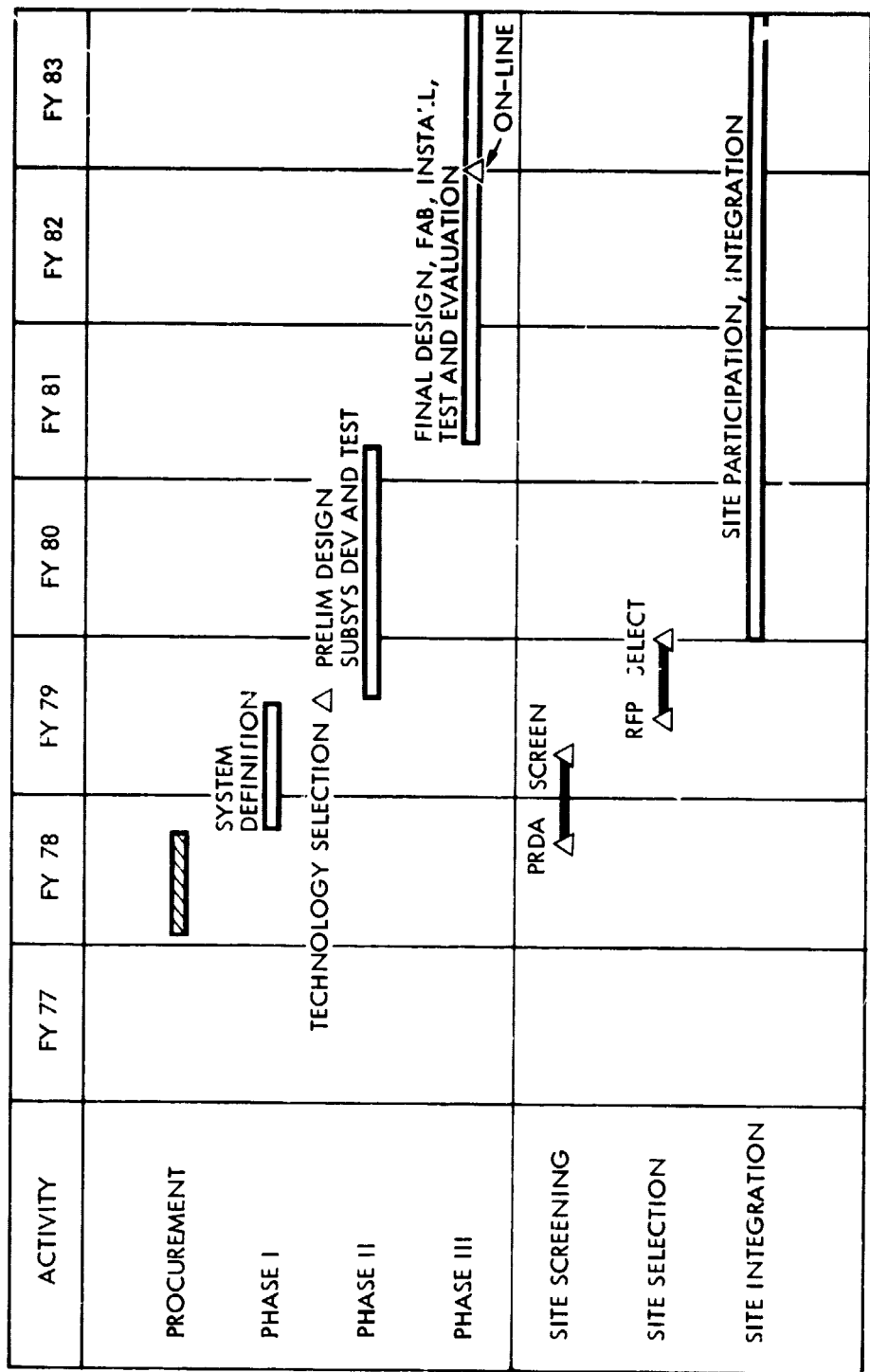


Figure 1. Schedule for the SPSA First Engineering Experiment

At the end of the phase I systems definitions studies, the technology approach and a general system design for the experiment will be selected. The second phase will then include the preliminary design of the selected system as well as development and testing of components and subsystems. Final design, fabrication, installation, and testing will be accomplished in the third phase. Experimental operation is scheduled to begin in late 1982.

3. Siting for the First Engineering Experiment

Siting for the first engineering experiment will occur in parallel with the development of the engineering system. A two-stage process is planned for site selection to minimize proposal costs for a large number of potential small community participants. Simple preliminary proposals will be screened, after which more comprehensive information will be furnished by a small number of potential site participants. Following selection, the successful site participant will be involved in planning activities, environmental assessment, and site preparation.

Participation requirements will be described in a Program Research and Development Announcement (PRDA). These are expected to include an available site of approximately 10 acres suitable for the plant, together with transportation, utility and maintenance services, and a suitable connection to a utility grid.

The DOE will provide, under separate contract, for the construction, installation and testing of the experimental solar thermal power plant, except for the distribution system elements. The plant design will be based on a point focusing solar thermal technology in which solar energy is concentrated by collectors that both track and focus to operate one or many high-temperature heat engines. (A background technology discussion is provided in Section II.) Several technology options are being investigated prior to final system design. Initial plant operation will emphasize the collection of experimental data rather than efficient production of electrical energy.

The application for this first engineering experiment is to be a small community with an electric demand load of less than 100 MWe. Site participation teams are expected to include, as a minimum, a community agency and an electric utility. Evaluation criteria for the first stage proposals will be described in the PRDA. It is expected that these will include evidence of commitment and capability of the participation team, availability and suitability of the proposed site, availability of direct solar energy, environmental factors, need for alternative energy sources, and community support.

C. OBJECTIVE AND SCOPE

The primary objectives of this study are to identify and discuss the issues associated with siting a solar thermal power plant with a utility/small community application and to define areas requiring further study. This study effort is a part of the siting activity for an experimental

1-MWe power plant, and the specific examples in the report are based on siting requirements for this experiment. However, many issues are expected to have a more general application.

The report provides a qualitative discussion of siting issues. Its intended usage is to provide a preliminary basis for the preparation of more detailed site requirements and site evaluation factors. It may also provide a useful background for potential site participants. Siting issues are discussed from both power system and site participant viewpoints. A general background description of applicable solar thermal technologies is followed by a discussion of issues.

D. APPROACH

Siting issues for solar thermal power plants were identified using conventional siting requirements as a baseline. Significant issues were then considered in conjunction with the requirements and impacts of solar thermal-electric technology. These issues have been grouped into three categories to provide a framework for the discussion of issues important for siting solar thermal-electric technologies with emphasis on small community/utility applications. The resulting siting issues are similar to those for conventional generation facilities with the exception of their groupings, the perspective in which they are viewed, and the emphasis placed on them. Documents referenced in this study are included in the bibliography. Additionally, much information of value was obtained at the Small Power Systems Solar Electric Workshop held in Aspen, Colorado, October 10-12, 1977 (Ref. 1).

Relationships between solar thermal-electric power plants and their sites may be categorized as effects of the site on the plant and effects of the plant on the site. Effects of the site on the plant will be discussed by identifying the resources and site characteristics desirable for construction, operation, and maintenance of a solar thermal-electric power plant. The effects of the plant on the site will be discussed by identifying the impacts plants may have on their sites, and how these site impacts may result in construction delays and even development termination. This report describes the relationship between solar thermal-electric power plants and their sites and delineates the information that should be assembled in order to make wise siting decisions.

II. TECHNOLOGY OPTIONS

A. BACKGROUND

This brief description of solar thermal power technology is included to provide background information relative to the siting issues identified. There are a variety of ways to utilize solar energy (insolation). Flat plate collectors can achieve temperatures sufficient for space and water conditioning, while photovoltaic systems can convert sunlight directly into electricity within photovoltaic cells. These systems utilize both the direct and diffuse components of the total available insolation. On cloudy days the amount of available insolation is considerably reduced, but some of the diffuse component is available due to scattering.

Solar thermal-electric systems require concentration of the thermal properties of absorbed sunlight to achieve temperatures sufficiently high to drive a heat engine. Some concentration can be achieved with linear focusing systems, such as Vee-trough, variable slot, and parabolic trough, which may be non-tracking or have single-axis tracking mechanisms. Acceptable engine efficiency requires the high temperatures associated with high concentration ratios. The remaining discussion is limited to high concentration point focusing systems with two-axis tracking mechanisms, such as central receiver systems and point focusing distributed receiver systems with central or distributed generation.

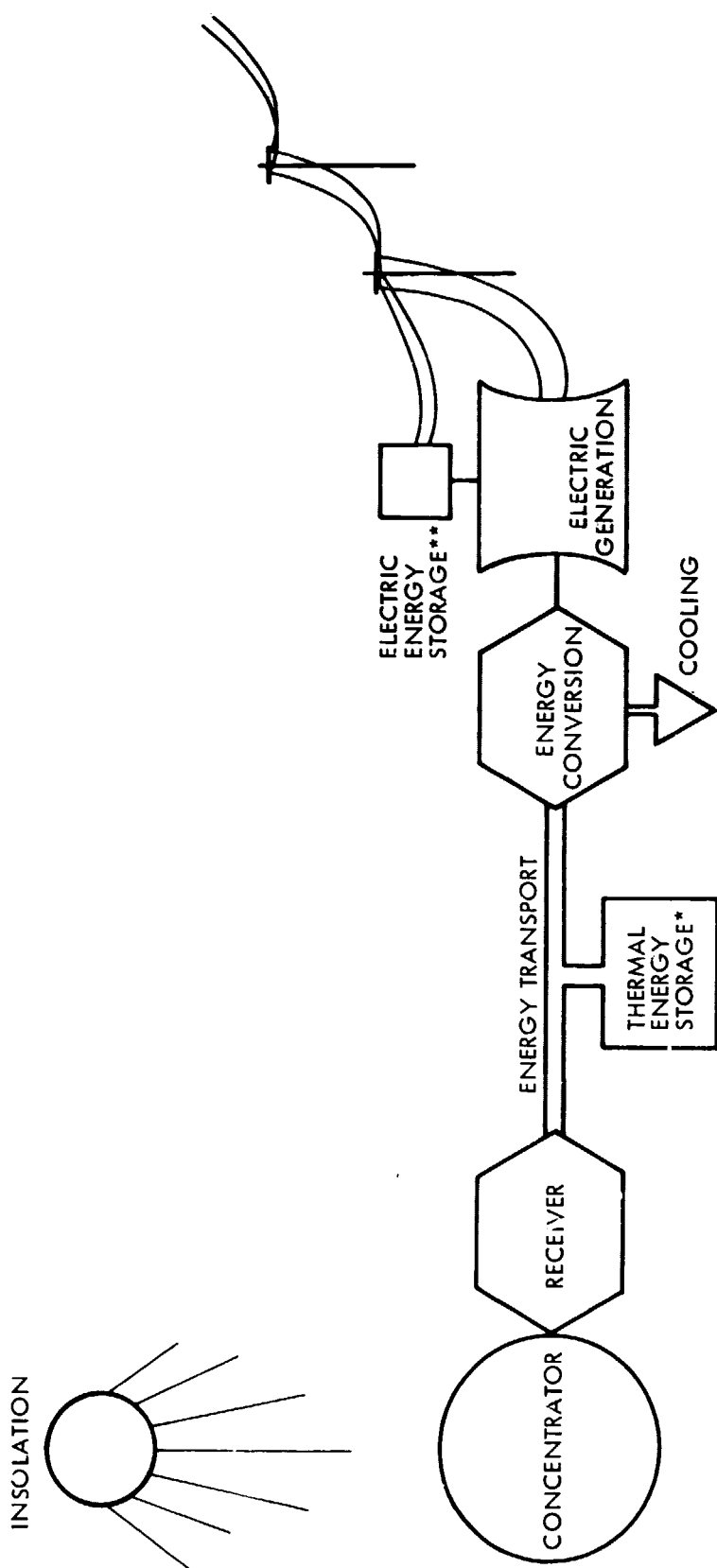
B. SOLAR THERMAL POWER OVERVIEW

The key elements of a solar thermal power system are shown schematically in Figure 2. Solar energy is collected by a tracking concentrator, which focuses energy on a receiver. The working fluid in the receiver is raised to a high temperature and is then transported to a heat engine, which converts the thermal energy into mechanical energy. This energy is used to generate electricity in a conventional manner. Energy storage may be incorporated as thermal storage in the thermal transport system, as mechanical storage following conversion or as electrical storage following generation. These functions must interact effectively as a total system to attain high overall plant efficiency.

1. Concentrators

The function of a concentrator is to reflect insolation and focus concentrated energy on a receiver. Two types of concentrators suitable for solar thermal plants are heliostats and point focusing parabolic dishes. Heliostats are utilized in central receiver plants while parabolic dishes are utilized with distributed receiver systems.

A field of heliostats focusing on a tower-mounted receiver functions in much the same way as a parabolic dish collector focusing on a receiver at its focal point. Just as small segments of a parabolic dish are relatively flat, so are the heliostats in a central receiver power plant. Heliostat designs typically include a slight parabolic curve and are



*Storage prior to conversion may be either thermal or chemical
 **Storage after conversion may be either electric or mechanical

Figure 2. Solar Thermal-Electric Conversion Subsystems

about 6 m by 6 m (20 ft by 20 ft) in size (Ref. 2). The distance between a heliostat and the central receiver in a 1-MWe plant may be several hundred feet. Therefore, tracking must be very precise to focus sunlight on the receiver. This increases sensitivity to local meteorological conditions and topography.

Point focusing dish concentrators are typically paraboloids approximately 12 m (40 ft) in diameter which concentrate direct insolation and focus it on receivers located at their focal points. Most concentrator designs utilize a framework supporting segmented reflector elements with a quadrupod receiver support connected to the basic frame. A tracking mechanism with a sensing device keeps the dish pointing at the sun (see Figure 4).

Concentrators must have structural integrity sufficient to withstand adverse meteorological conditions. Wind is a problem to all concentrator designs but especially to heliostats because of their flat shape and precise focusing requirement. During high wind conditions, some designs include non-operating stowage positions to reduce damage potential.

Reflective concentrator surfaces may be damaged by wind blown material. These surfaces may be composed of first or second surface glass, backsilvered glass, or reflective metallic tape and film. Heliostat and parabolic dish concentrator designs trade off structural integrity against lightweight, low-cost construction. Both heliostat and parabolic dish designs have two-axis tracking mechanisms to achieve high concentration ratios and high temperatures.

2. Receivers

Receivers, either the cavity or exterior type, transfer heat from concentrated insolation to a working fluid. Receiver designs vary widely. A typical cavity receiver design for a 15-kWe distributed collector consists of a cavity with coiled, pressurized tubes containing transfer fluid. It may be approximately 0.6 m (2 ft) in diameter and 0.9 m (3 ft) long, weighing about 150 kg (330 lb). The transfer fluid characteristics are matched with the receiver design.

3. Energy Transport

Once solar radiation has been transferred to a working fluid in the receiver, the fluid transports the energy to a heat engine or turbine. Some alternatives for transport fluid are pressurized hot water, superheated steam, liquid metal, hot inert gas (helium), and chemical transport (methane and steam). Solar thermal power plants with engines or turbines adjacent to receivers have minimal heat loss problems. Central receiver power plant designs generally locate the generation equipment at the base of the tower, thus reducing transport distances. However, distributed receivers with central generation are more susceptible to heat loss because they must transport energy from each concentrator to the generation equipment.

4. Energy Storage

To extend generating capability into evening hours and to allow continuous daily generation on days with intermittent cloud cover, solar power plant designs generally include energy storage subsystems. Storage systems may store sensible heat, mechanical energy or electrical energy. The various storage options interact with different phases of the solar thermal system. Sensible heat may be stored prior to conversion. Mechanical energy is stored after conversion but prior to electrical generation. Electrical energy is stored after generation.

Sensible heat storage may consist of an underground pit filled with rock and fluid in which hot fluid from the receivers releases heat to the rock and fluid. The heat remains in storage until required, when it is transferred to a circulating fluid, which transports the heat to the conversion system.

Mechanical storage after conversion could consist of a system in which water is pumped to an elevated reservoir. Electricity is then generated as required from the stored potential energy.

Electrical energy can be stored in batteries following generation. The present state-of-the-art is conventional lead-acid batteries. However, advanced electrical storage techniques are currently being developed.

5. Energy Conversion

The energy conversion subsystem is one of the most critical elements of a solar thermal power plant. It is in this subsystem that thermal energy is converted to mechanical energy in a heat engine. Optimal operating conditions dictate the temperatures of the working fluid and hence the concentration ratio. The working fluid is a function of thermal properties required by the receivers and generation equipment. The type of transport is a function of the working fluid's temperature and corrosive capability.

Heat engines for a solar thermal power plant produce mechanical work from a heat flux. The heat flows from a high-temperature source through the engine, thereby converting a fraction of the heat into mechanical work while rejecting the remainder at a lower temperature. The thermal efficiency of an engine may be defined as the mechanical work output divided by the heat input. The theoretical maximum efficiency of a heat engine depends on the ratio of the input and rejection temperatures. Achievement of high engine efficiency requires not only a high temperature ratio but also internal processes to exploit this temperature ratio without introducing excessive thermodynamic losses. The lower end of the temperature ratio is limited by the heat rejection, or cooling, subsection while the upper end is limited by the concentration ratio and receiver material capabilities.

Heat engine efficiency is important from three perspectives. First, high efficiency yields a given power output with a lesser amount of solar energy. This, in turn, allows a smaller collector field, thereby saving

both collector cost and land area. Second, higher efficiency can provide for savings in the receiver, energy transport, and energy conversion (heat engine) subsystems. Third, engine efficiency directly affects the requirements for waste heat rejection, which can be considered to be the inverse of the work output equation. If an output of 1 MWe is to be provided with an engine efficiency of 50%, the thermal energy input would have to be 2 MWe with a heat rejection requirement of 1 MWe. If the heat engine efficiency is only 10%, 10 MWe of thermal energy input are required, and 9 MWe must be rejected as waste heat. As discussed in later sections, the heat rejection, or cooling, requirements can be a significant part of the system, site, and resource requirements.

A solar thermal power plant may utilize Rankine, Brayton (open or closed) or Stirling cycle engines. A single Rankine steam turbine or a Brayton gas turbine can be used for central energy conversion in either a central receiver plant or a distributed receiver plant using thermal transport. Small heat engines attached to distributed receivers for distributed generation may utilize a Brayton, Stirling, or, even, Rankine cycle.

6. Cooling

All heat engines require cooling to reject the thermal energy not used in energy conversion. The cooling subsystem controls the lower end of the engine temperature ratio and hence affects engine efficiency. The type of cooling system used depends on the type of engine, the amount of cooling required, cost, and the availability of a cooling medium. Some types of cooling systems are: flow-through, evaporation ponds, wet and dry mechanical draft towers, and wet and dry natural draft towers.

Cooling requirements can be quite large. The make-up water required for evaporative cooling in a 1-MWe plant is estimated to be over 30 m^3 (1000 ft^3) per day. As previously discussed, a 1-MWe plant requires 1 MWe of heat rejection for an engine efficiency of 50% and 9 MWe for 10%. One way to visualize cooling requirements is to consider a steam turbine in which the working fluid must be condensed at the end of the cycle. If evaporative cooling is used, the water evaporated must roughly equal the water (steam) condensed. A cooling method summary is shown in Table 1.

C. OPTIONAL SOLAR THERMAL SYSTEMS

Three potential technologies for a point focusing solar thermal power plant are: (1) central receiver, (2) distributed receiver with central generation, and (3) distributed receiver with distributed generation.

1. Central Receiver

As previously discussed, a central receiver plant consists of a field of collectors called heliostats, oriented so that they focus sunlight on a common receiver located on a tower in a central location. Each heliostat has a two-axis tracking mechanism, which allows it to remain focused on the receiver. The distance between heliostats and receivers requires extremely

Table 1. Advantages and Disadvantages of Several Cooling Methods (Ref. 3)

Cooling Method	Advantages	Disadvantages
Flow-through	Thermally efficient	Water resource required Thermal impact
Evaporation ponds	Thermally efficient	Land area required Water resource required Water quality impact
Wet cooling towers	Thermally efficient	Water resource required Meteorological impacts Noise and water quality impact
Dry cooling towers	Minimal water requirement Minimal impact on local meteorology	Less thermally efficient Larger tower-visual impact Cost
Natural draft towers	No electrical fan required	Relative large structure required Visual impact
Mechanical draft	Structure smaller Less visual impact	Electrical fan required

precise focusing. The working fluid in the receiver is transported to the base of the tower where a turbine converts thermal energy to mechanical to generate electricity. A pictorial representation of this system is shown in Figure 3.

2. Point Focusing Distributed Central Generation

Distributed receiver plants with central generation typically utilize parabolic dish solar collectors. Each receiver pipes energy transfer fluids to a single engine, from which the entire electric load of plant is generated. A pictorial representation is shown in Figures 4 and 5a.

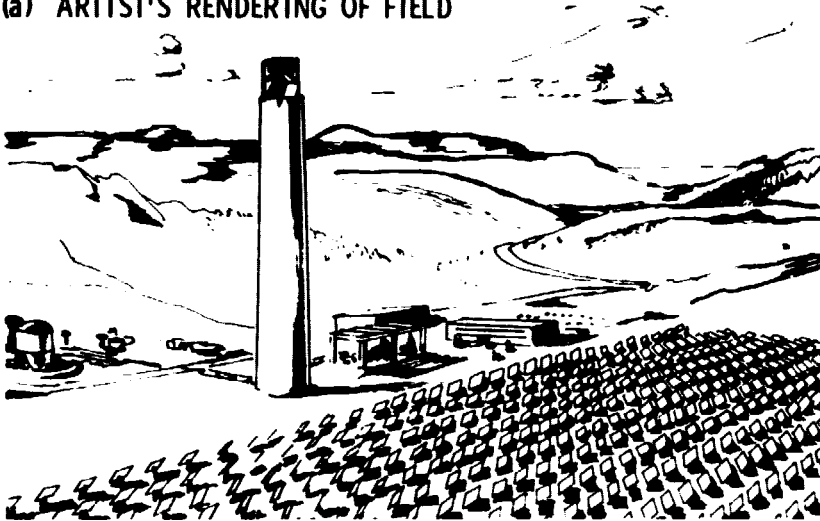
3. Point Focusing Distributed Receiver and Generation Systems

Point focusing distributed generation plants are composed of a field of parabolic dish solar collectors. The paraboloid shape allows

each collector to concentrate direct solar insolation and focus it on receivers located at their focal points. The working fluid from the receivers is used to drive heat engines, from which electricity is generated. Each collector in the point focusing distributed generation system has its own engine, and thus electricity is produced at each collector. The heat engines at each collector may be located at the focal point or behind the collector. The focal point location requires increased support structure while the dish location requires thermal transport.

The aggregate electricity from all of the collectors in the field forms the plant's generating capacity. Because of their modularity, distributed generation systems lend themselves to a wide variety of applications. The quantity of electricity may vary from that generated by a single collector to that generated by any number of collectors. Unlike the cooling systems that may be utilized by central generation plants, distributed generation plants use distributed cooling. See Figures 4 and 5b for a pictorial representation.

(a) ARTIST'S RENDERING OF FIELD



(b) SCHEMATIC OF CENTRAL RECEIVER SYSTEM

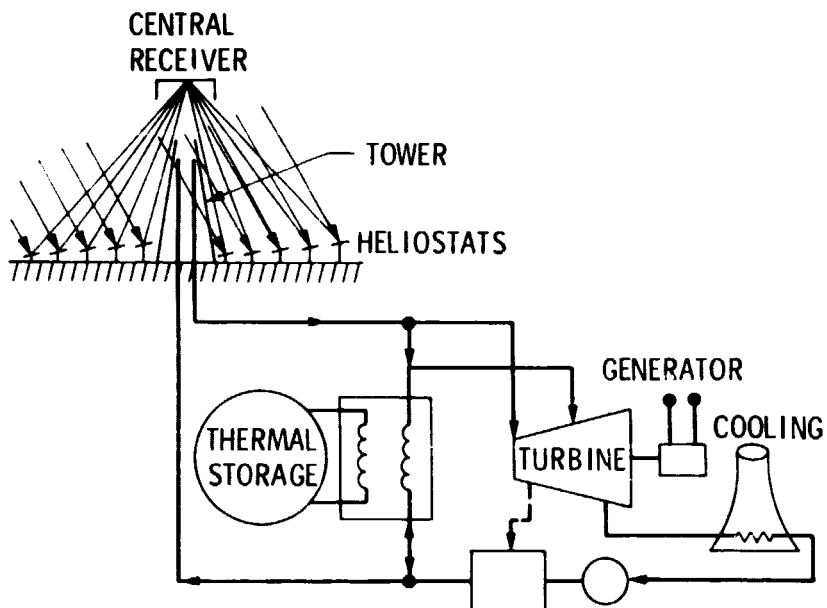


Figure 3. Central Receiver System

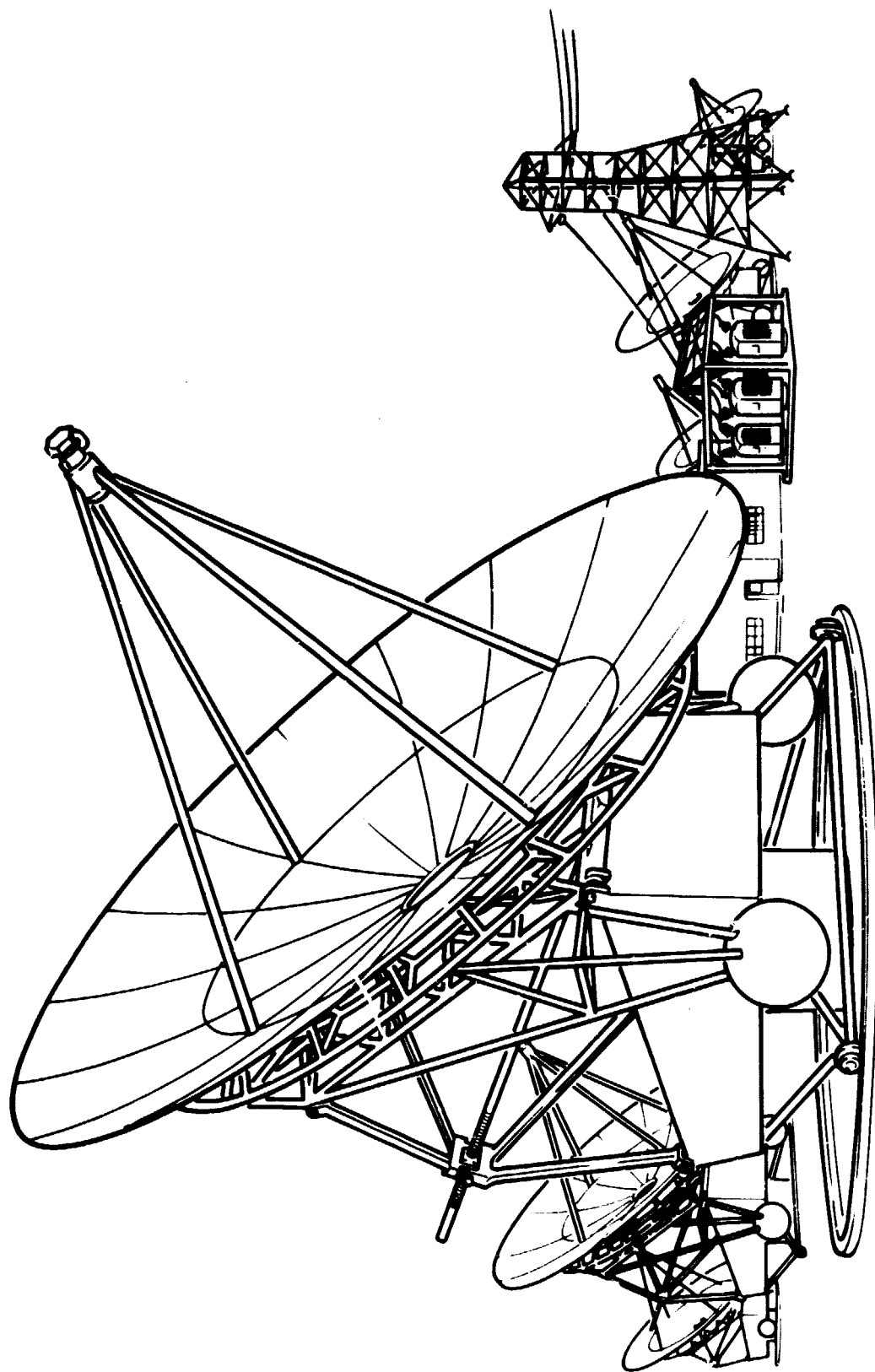
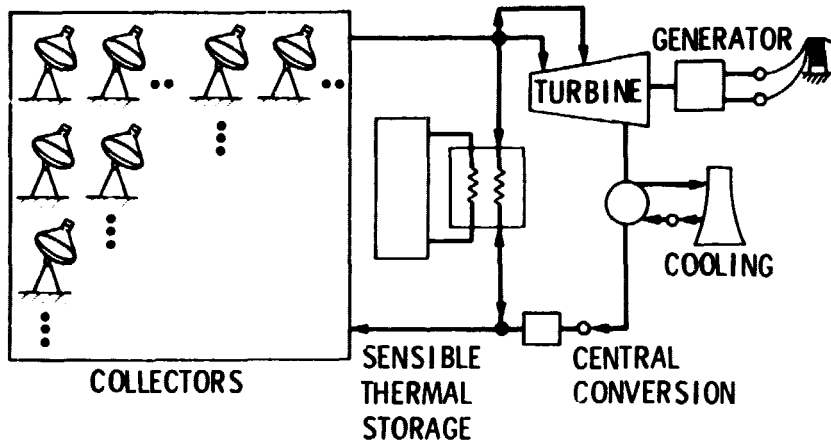


Figure 4. Parabolic Dish Collector Field

(a) WITH CENTRAL CONVERSION



(b) WITH DISTRIBUTED CONVERSION

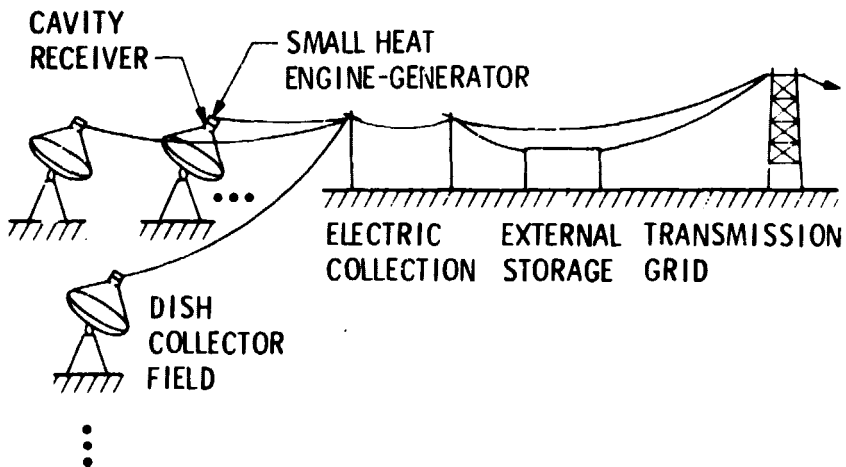


Figure 5. Point Focusing Distributed Receiver System

III. SYSTEM RESOURCES

This section of the report identifies siting issues that arise from the resource requirements of solar thermal-electric power plants. In previous sections the technology options for the first engineering experiment were described. With that knowledge the reader will be able to see why the resources discussed in this section are necessary and thus have a better understanding of the siting issues that arise as a result of resource requirements.

The resources needed to construct and operate solar thermal power plants include: (1) appropriate quantity and quality of insolation, (2) adequate water supply, (3) construction materials and manpower, and (4) suitable land area.

A. INSOLATION

In the discussion of various solar energy technologies, a distinction was made between those technologies that can utilize all of the sun's radiation reaching the earth and those that can only utilize the direct component of radiation--the solar thermal-electric systems. In this section insolation as a fuel for solar thermal-electric systems will be discussed in more depth to give the reader a better understanding of the siting problems associated with it.

Insolation is the interception of the sun's radiation by exposed surfaces. As the sun's rays penetrate the earth's atmosphere, various components are absorbed, reflected back into outer space, and scattered by gas molecules, water droplets in clouds, and dust particles. The quantity of radiation which actually reaches the earth's surface is significantly less than that reaching the upper atmospheric layers. Of the solar radiation reaching the earth's surface on a sunny day, up to 10% may be scattered or diffuse; the remainder is direct insolation. Cloud cover significantly alters the quantities of direct and diffuse insolation reaching the earth's surface according to its thickness and density. Direct insolation can be totally reflected back into space and diffuse insolation may be somewhat increased or decreased depending on cloud characteristics.

As indicated in the technology description section, the solar thermal-electric systems in the SPSA Project all use concentrating collectors to achieve high temperatures. Because diffuse insolation cannot be effectively concentrated, these solar technologies are dependent on direct insolation. As a result, meteorological conditions become an important siting concern. Insolation data collected on two consecutive days in January at Barstow, California illustrate the change in insolation intensity resulting from changing meteorologic conditions, in this case cloud cover (Figure 6). In areas where insolation availability is variable, tracking the sun may be more difficult and require system designers to improve tracking capabilities. If insolation is very transient, it may not be worthwhile to operate the plant. Solar thermal power plants operate much more efficiently in conditions of steady insolation. Thus, of two sites with equal amounts

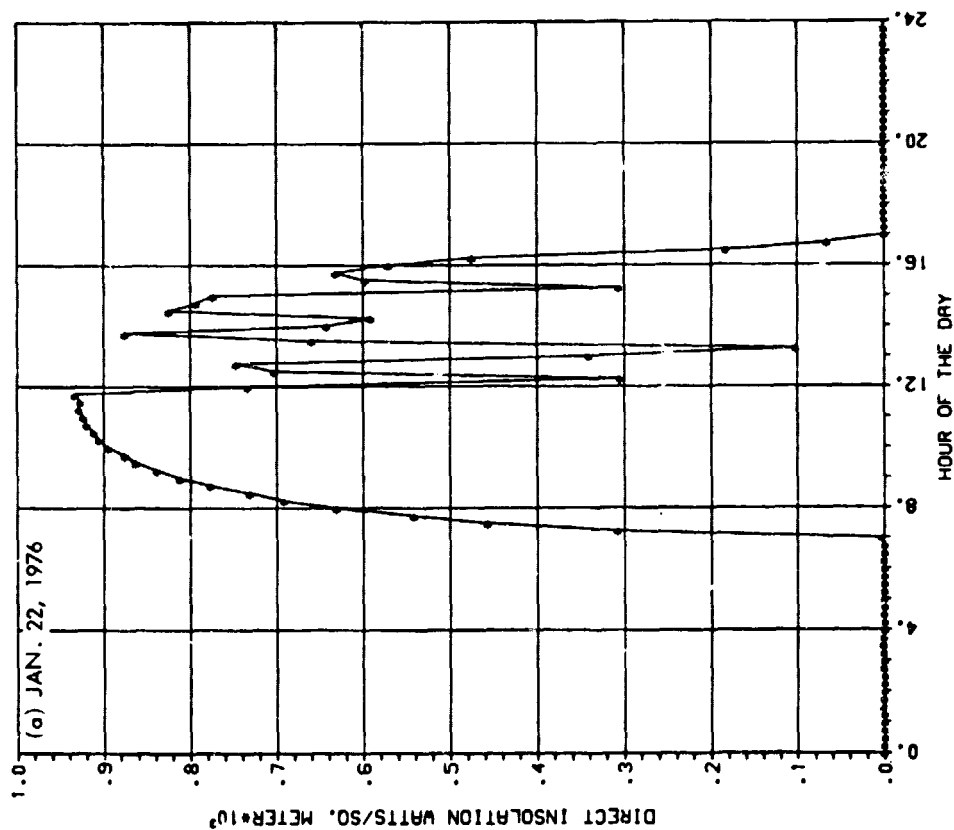
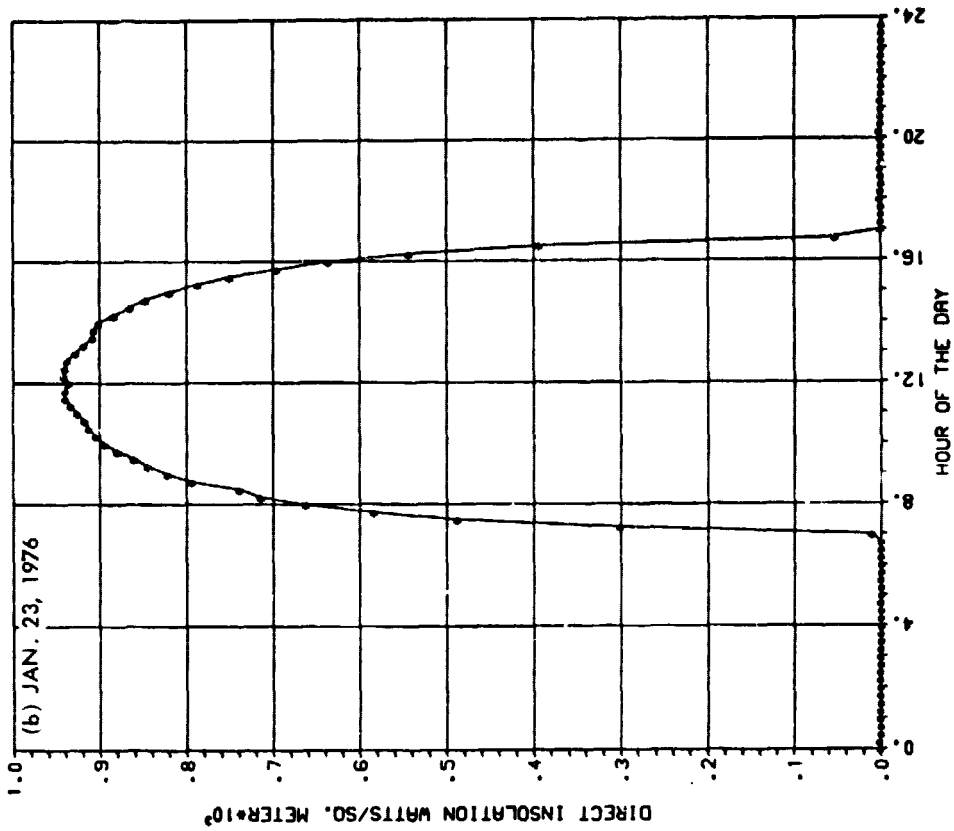


Figure 6. Representative Total Insolation, Barstow

of direct insolation per day, the site with steady insolation is preferred to the site with intermittent cloud cover.

To fully evaluate a site for solar thermal-electric systems, the quantities of direct insolation available must be determined. This information is not readily available. The collection of insolation data requires special instruments, such as pyroheliometers, tracking heliometers, and pyranometers which are not available at most stations. Even when insolation data are available, they may not differentiate between direct and diffuse components of sunlight; only total insolation may have been measured. The best available insolation data are data tapes assembled by the Aerospace Corporation in El Segundo, California. Sandia Laboratories in Albuquerque, New Mexico, Southern California Edison in Rosemead, California, and the Gene Carter Army Atmosphere Laboratory in Huntsville, Alabama, also have insolation data. The data collected by these institutions are from meteorological stations located throughout the country. General meteorological data, including insolation, is available from the National Climatic Center in Asheville, North Carolina, and in the Climatic Atlas published by the National Weather Service, but these data do not differentiate between direct and diffuse sunlight and generalize data over large areas.

Presently, researchers are developing models to predict the quantity of direct insolation received at a site from general meteorological data. For instance, the number of cloudless days per year may be the only input data required. Other models and methods are being developed to determine the quantity of direct insolation received given the total insolation. These methods and models will greatly facilitate site selection with regard to insolation because site evaluators will require much less data to determine direct insolation levels. Figure 7 depicts direct and total insolation received on two days in December 1974 at Goldstone. This is the type of data which may be generated by the models described above; however, in this case tracking heliometers and pyranometers measured the insolation levels.

B. WATER

Solar thermal power plants, depending on design, may require water for cooling, make-up, maintenance, and energy transport. The requirement for cooling in solar thermal-electric power plants was described in the technology description section of this report. The amount of water required for cooling depends on the technology utilized.

Solar thermal power plants may also require water for energy transport. High water quality is required to avoid the deposition of impurities within transport pipelines. Solar thermal-electric systems using steam or hot water to drive turbines will require water to replace losses due to evaporation and cooling tower "blowdown."

Because high concentrator reflectivity is important to a solar power plant's efficiency, the collectors must be kept free of dust, dirt, and other particulate matter. The frequency and method of concentrator cleaning are functions of the type of concentrator as well as the

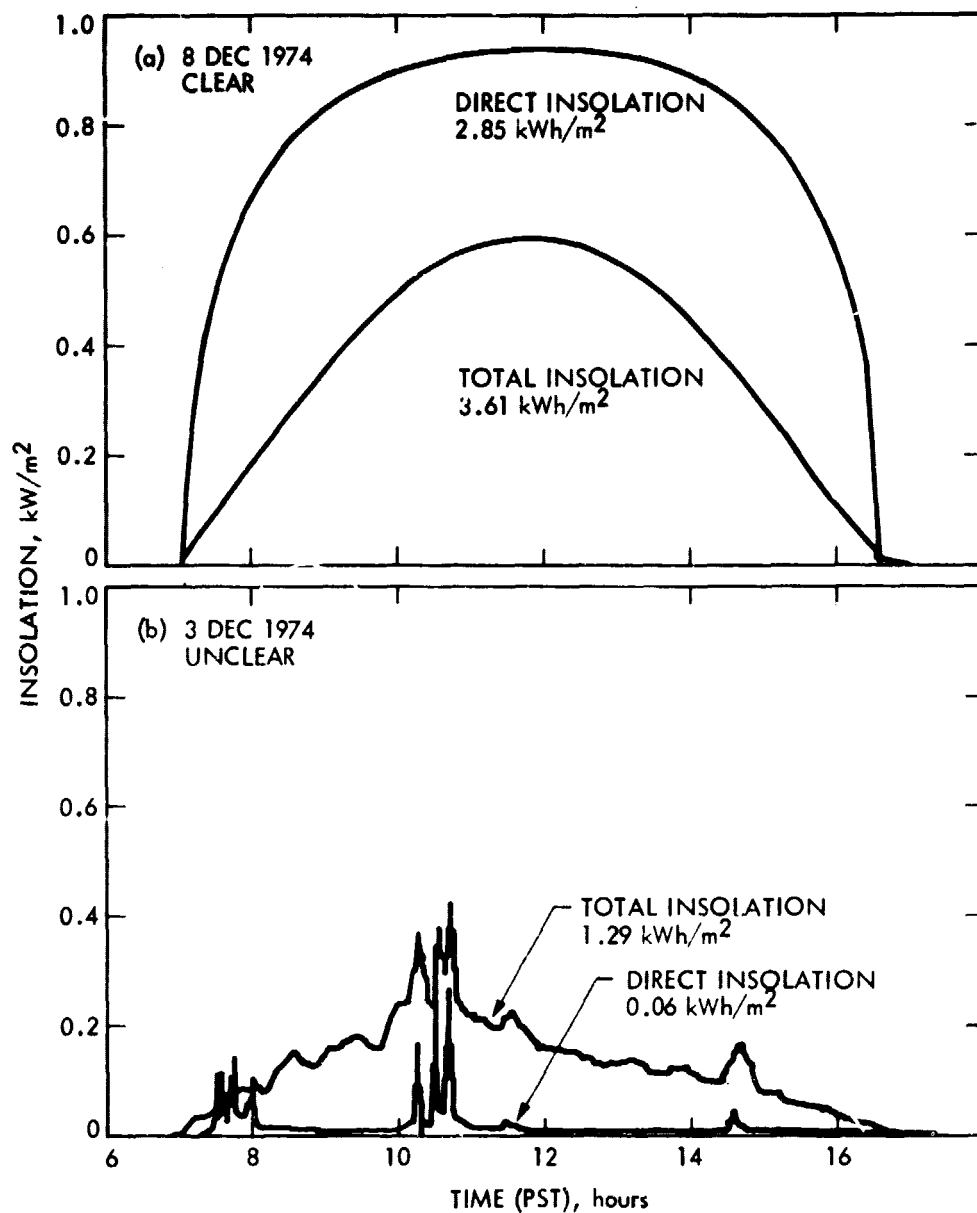


Figure 7. Direct and Total Insolation

quantities of particulate matter in the atmosphere. However, it is expected that water will be a part of the cleaning system in some quantity.

C. CONSTRUCTION MATERIALS AND MANPOWER

Construction, operation, and maintenance of solar thermal power plants will, like other developments, require construction materials and manpower. Site preparation prior to plant installation is an important phase of plant construction and is to a degree dependent on topographic and geologic site characteristics. These site preparation activities may include: grading for collector bases and roads, road development, plant fencing, and the acquisition and transportation of materials required by these activities. The materials, equipment, and manpower required for these activities will either come from adjacent communities or be imported from more distant parts of the region. Sites with these resources readily available will allow site preparation activities to be performed more quickly and economically than sites without them. Less resources will be required for plant operation and maintenance.

The frequency and type of maintenance required by solar thermal-electric power plants is currently unknown. However, several maintenance activities are expected. The collector's reflective surfaces will require cleaning. Drainage and service pathways may need clearing, repairs will be needed, and inspections made. Additional maintenance activities will be identified for solar thermal system as they are developed.

D. LAND

The land area required by typical 1-MWe solar thermal-electric power plants is approximately 10 acres. This is a function of the assumed insolation intensity, and the amount of electricity the plant is designed to generate. Lower average insolation requires more collectors and larger areas of land to produce the same amount of electricity. The solar thermal-electric system for the first engineering experiment will be a uniform size, regardless of where sited; the collector area will remain the same. Therefore, the average amount of electricity generated by the first experimental systems will vary from site to site as a function of meteorological conditions. The approximate 10-acre site for a 1-MWe plant contains all subsystem facilities and support structures such as maintenance buildings and service access and facilities. Additional land may be acquired for public information centers.

In addition to the acreage required for solar thermal power plants, there are other land characteristics that are important to siting, for example, adjacent land use. There are many industrial processes which produce effluents capable of eroding collector surfaces and blocking insolation. Industries utilizing highly flammable or explosive materials should also be avoided to avert damage to the plant from projectiles hurled by explosions.

The height of adjacent land uses is also important. The site selection criteria included in the Program Opportunity Notice (PON) for a 10-MWe central receiver power plant developed by ERDA (now DOE) stipulate that: "Potential site locations should have an uninterrupted view to the south down to an angle of 10 degrees above the horizon extending from the local southeast to southwest direction... control of adjacent property through legal restrictions or outright acquisition may be necessary to satisfy this requirement" (Ref. 4). Specifications of this type will be developed by system designers for the system used in the first engineering experiment. Future land uses adjacent to the solar thermal power plant site should also be considered. A guarantee of unlimited "sun rights" into the future may become part of a new body of law dealing with solar energy technology (Ref. 5).

Other site characteristics are land form types. Solar power systems are sensitive to ground movement because of the precise focusing required. Therefore, sites proposed for them should be carefully evaluated to identify underlying or nearby geologic characteristics and their possible impacts. The most damaging geologic phenomena to be evaluated are earthquakes. Faults on or near the proposed site should be evaluated thoroughly. Active faults on the proposed site or near enough to cause damage to the plant may make that site unacceptable. In an Aerospace study, areas exceeding shaking of 0.26, or earthquakes of magnitude 7 on the Richter scale, were identified as unsuitable for solar thermal plants (Ref. 6, pp. 51-54).

Soil types are capable of increasing the impact that earthquakes have on surface structures. Alluvium is very unstable and tends to magnify earthquake shock waves. Other soil types to be avoided because of their instability are sand, dry lake sediments, expansive soils, and soils prone to liquefaction.

To achieve maximum efficiency, each collector in a field should be oriented to collect the maximum amount of sunlight. Thus, shading from the collectors themselves and from the surrounding terrain should be minimized. On sloping sites the slope should face south, instead of north. On flat terrain shading can be overcome by spacing the collectors correctly, but enough flat terrain may not always be available. It is not expected that sites with average surface grades greater than 20% will be considered for solar power plant sites; however, even on grades less than 20%, spacing and orientation difficulties may be present (Ref. 6, p. 36). Actually, it is not expected that slopes of over 10% would be acceptable for solar power plant sites. To obtain the required spacing, larger land areas will be needed in contoured topography than on flat sites. Other disadvantages of contoured sites are that plant installation may be more difficult and may require more grading and other site preparation. The less site alteration necessary, the fewer the environmental impacts from erosion, landslides, stream silting, flooding, and destruction of natural habitats, and the lower the site preparation costs.

IV. PHYSICAL ENVIRONMENT

The previous section of this report dealt with the siting issues that arise as a result of the resource requirements of solar thermal-electric plants. In this section siting issues that arise as the result of meteorologic conditions will be identified. Meteorological or weather conditions must be taken into account to some extent in all development projects. The extent to which meteorology must be considered depends on the sensitivity of the development project to it. Solar thermal power plants have some unique sensitivities.

The concentrator is the subsystem most sensitive to meteorologic conditions in a solar thermal power plant. As described in the technology description section, they are designed to be relatively lightweight for tracking purposes and cost and, of necessity, are thin-walled and have fragile reflective surfaces. For maximum exposure to the sun, they should be unprotected by topography, vegetation or man-made structures. Some collector designs are shielded by enclosures made of transparent materials; however, these structures are themselves sensitive to meteorological conditions.

Another subsystem that may be sensitive to meteorological conditions is the cooling system. Many cooling systems utilize evaporation, where efficiency is dependent on the characteristics of the atmosphere. The degree of this dependence is related to the cooling technology selected.

Solar thermal power plants must be designed to withstand meteorological conditions from two perspectives: operation and survival. For example, a plant will be designed to operate in winds up to a specified limit, and when winds exceed that threshold, the plant will be designed to discontinue operation but withstand the wind without significant damage. The percentage of time a solar thermal power plant must cease operation due to meteorological conditions may be traded against other site characteristics during site selection.

A. WIND

Wind may impact solar thermal-electric power plants in two important ways. First, its force and speed alone may be damaging. Secondly, it may carry particles of sand, dirt, and dust capable of scratching the reflective surfaces of concentrators. In many areas where wind is not obstructed by topography or vegetation, or where it is funneled through a topographic venturi, it can achieve high velocities. It is highly likely that solar thermal power plants may be located at such sites because of their requirement for terrain and vegetation which do not block insolation. Because of their size and shape, solar thermal collectors may induce high drag forces, and, as a result, they may be damaged by high winds.

The results of one central receiver system study indicate that winds of over 14 m/s (31 mph) should occur at the plant site less than 1% of the time (Ref. 7). This study further states that, "Plants of this central receiver system should withstand and operate in gusts up to 25 m/s (55 mph),

and survive without damage winds of 40 m/s (90 mph)" (Ref. 7). To do this, the collectors are designed to attain a less wind resistant, or stowage, position.

The operational and survival wind speeds quoted here for central receiver systems are exemplary only. They are intended to give the reader an understanding of wind/system interactions and a method of dealing with them. Design wind loads for each solar thermal plant will be determined during system design.

To assist system designers assess the wind velocities their solar systems should be able to withstand, and to assist site evaluators selecting a site, information about wind patterns should be available. The type of information required is similar to that required for airports, i.e., wind roses (see Figure 8). Prevailing wind direction and speed, recorded wind speed extremes, gusts, and seasonal variation are also important.

Besides collector structural damage, winds can damage reflective surfaces by abrasion from sand, dirt, and dust particles. These surfaces may be made of reflective films, metals, and first or second surface glass and must retain their reflectivity to keep the plant operating effectively. Strong winds carrying sand and dirt may scratch reflective collector surfaces until they can no longer efficiently reflect sunlight.

In addition to data describing prevailing wind conditions, information on blow-sand conditions should be available at each respective site. The frequency of wind storms carrying sand, dirt, and dust should be indicated as well as the type and abrasive capabilities of these particulates (see Table 2).

B. PRECIPITATION

Rain, hail, snow, etc., impact solar thermal-electric systems in a variety of ways. This section identifies some of the problems these impacts could create.

Rain alone is not responsible for creating hazardous conditions to solar systems, but works together with topography and soil-slope stability. The evaluation of possible sites in areas receiving heavy rainfall should include a detailed analysis of soil type and slope stability. This evaluation is also indicated as necessary in the previous discussion of land suitability. Rain may cause landslides, erosion, and flash flooding. It is not expected that solar plants will be located near slopes steep enough to be concerned with landslides but sites susceptible to flash flooding, periodic flooding, and erosion should be identified.

In all candidate systems mitigation measures decreasing the impact of flooding and soil-slope slippage may be utilized. Some simple measures to improve a site with regard to flooding and slope stability are the installation of drainage ditches, percolation basins, and the revegetation

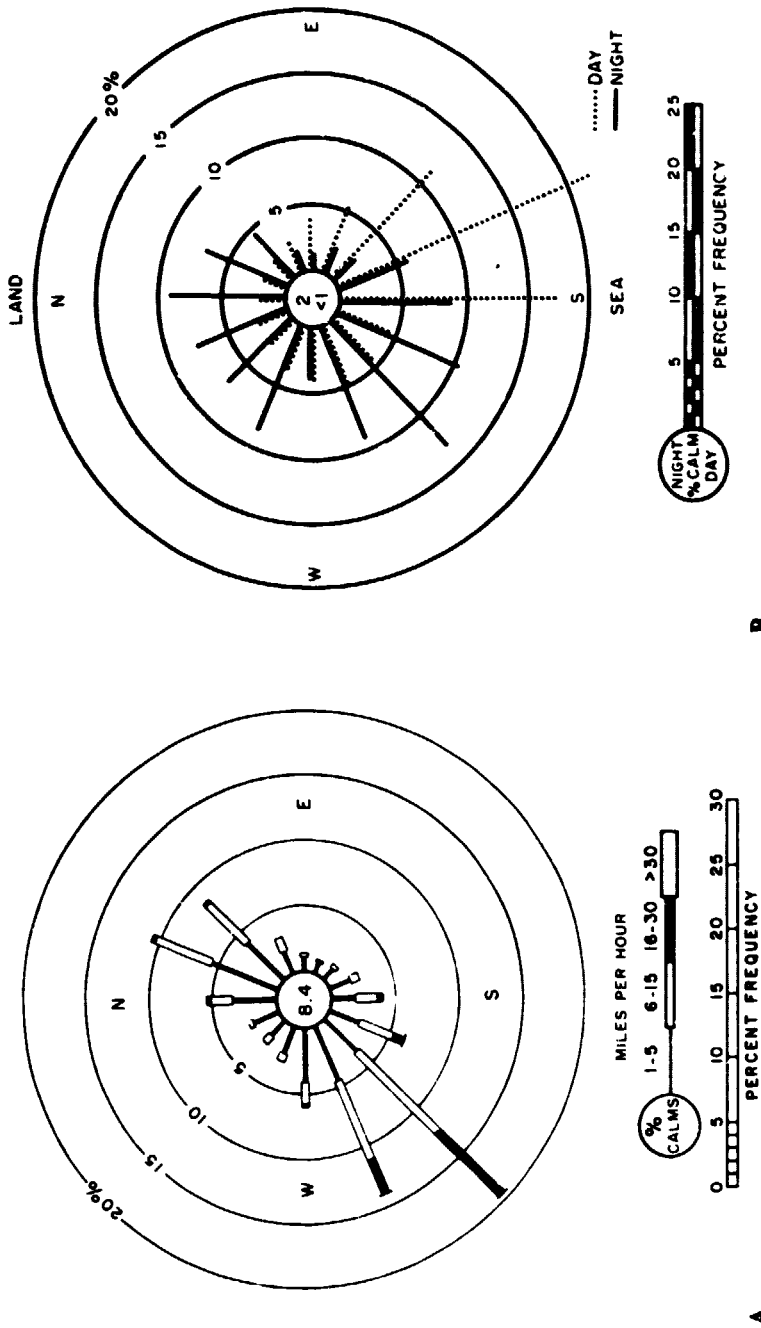


Figure 8. Wind Roses (Ref. 8)

Table 2. Soil Susceptibility to Wind Erosion (Ref. 9)

Four ratings have been used to show the degree of susceptibility to wind erosion. Following each rating is shown the soil texture groups, presence of cobbles, and extent of exposure to wind.

<u>Slight</u>	Soils of moderately fine and medium textures, and coarse texture soils with 40% or more cobbles on the surface.
<u>Moderate</u>	Soils of moderately coarse textures with 25 to 40% cobbles on the surface, and all soils that are protected from erosive winds.
<u>Severe</u>	Soils of moderately coarse and coarse textures with 10 to 25% cobbles on the surface, and all soils that are partially protected from erosive winds.
<u>Very Severe</u>	Soils of coarse textures that have less than 10% cobbles on the surface and that are exposed to erosive winds.

of all disturbed slopes. The previously mentioned central receiver study (Ref. 7) developed site selection criteria that limit average annual rainfall to 750 mm (30 in.) and limit the amount of rain falling within a 24-hour period to 75 mm (3 in.). Criteria of this type will be developed during design.

Hail, falling on fragile reflective surfaces, may be capable of damaging them, thereby rendering them useless as reflectors. Both hail and snow may also significantly affect solar collectors due to their weight alone. Tracking mechanisms may not be strong enough to operate when collectors are filled with hail or snow, and the support structures may give way in these conditions unless designed to bear their weight. Additionally, the maintenance costs of keeping collectors free of hail and snow, if necessary, may be high. Data indicating hail and snow characteristics should be collected by either system designers or site proposal teams prior to final site selection.

The central receiver study indicates that a solar thermal power plant should survive 20 kg/m^2 (5 lb/ft^2) of snow at a deposition rate of 0.3 m (1 ft) in 24 hours. It should also survive freezing rain and ice deposits in a layer 50 mm (2 in.) thick (Ref. 7). Again, these figures are exemplary only. Data describing precipitation extremes and averages should be available to system designers at each prospective site for final site selection.

C. TEMPERATURE AND AIR QUALITY

Every area has seasonal temperature extremes, temperature differences between day and night, and average, yearly, seasonal, and daily temperature changes. The goal of solar thermal-electric power plant design is to construct plants which will continue to function efficiently in various environmental conditions. The most environmentally sensitive part of collectors are the reflectors. Any warping or distortion of reflective surfaces would decrease overall plant efficiency. The central receiver system studied by Sandia describes operational ambient temperatures as -30°C (-20°F) to $+50^{\circ}\text{C}$ ($+120^{\circ}\text{F}$) (Ref. 7).

The cooling subsystem may also be impacted by temperature, especially if it utilizes evaporation. The efficiency of evaporation is a function of ambient air temperature and humidity as indicated in previous discussions. For example, natural draft wet cooling towers perform best in areas with high relative humidities and mild temperatures, and perform poorly in regions with low humidities and high ambient temperatures.

Air pollutants may impact the reflective surfaces of collectors in several ways. Particulate matter deposited on them will block insolation, chemical reactions induced by these pollutants may damage these fragile surfaces, and poor air quality can block some direct insolation from reaching the earth's surface.

V. SOCIAL/INSTITUTIONAL ISSUES

Up to this point the issues identified have been concerned with the physical needs and capabilities of solar thermal-electric systems. Because electric utilities provide a valuable commodity to a large number of people, they must operate in a reasonable and safe manner while meeting their customer's needs. Solar thermal-electric power generation, a new technology must prove itself in these regards. This section deals with issues which may result from the integration of solar thermal-electric systems into the local social and institutional structure.

A. LEGAL-REGULATORY

The legal-institutional environment is composed of regulatory and organizational requirements that delineate procedures minimizing disturbance to neighboring developments, the natural environment, and the general public which accrue from the construction and operation of new developments. Regulatory agencies and regulations differ from site to site because the subjects of regulations (for example, natural resources, public health, and economic development) differ. However, there are broad categories of regulations and regulatory agencies that are common to all sites, and there are development projects that require the involvement of specific types of regulatory agencies at all sites. Table 3 indicates some of the agency types which may be involved in the development of solar thermal-electric power plants.

The body of law and regulation is important to solar thermal-electric power plant siting because of the possibility that some regulations may preclude solar development. First, regulations can prevent the acquisition of construction and operation permits. Second, regulatory agencies can attach conditions to the permits which may cost the developer more than the benefits he expects to receive from his development. Third, the time required for permit acquisition may be too lengthy and procedures too complex for the time and money resources available.

Solar thermal-electric power technology is new, and, therefore, very few (if any) regulations specifically governing solar thermal power plant activities exist. Regulatory agencies are unfamiliar with solar plant processes and consequently are unsure which regulations may apply to them. Therefore, the first experimental solar systems may have to deal with conditional permits and time delays beyond those required of conventional development projects.

Because of possible regulatory time delays and conditional permits, sites with regulatory agencies experienced in handling various types of development projects and sites with proposal teams who have experience in dealing with regulatory agencies may be preferred to sites without this experience. Alternatively, a site with relatively simple regulatory procedures may be preferable to a site with complex regulatory requirements, regardless of the experience of the regulatory agencies and proposal

Table 3. Regulatory Agencies

Land Use	National Park and Forest Land Bureau of Land Management Military Land Coastal Protection Commissions State Lands Regional, County and City land use plans Municipal zoning ordinances
Construction	Building Codes
Safety of Personnel	Occupation health and safety agencies
Pollution Control	Air and Water Quality Agencies Health Agencies
Wildlife Protection	Fish and Game Agencies
Historical/Archeological Protection	Historical Preservation Agencies
Electric Utility	Public Utilities Commissions Federal Department of Energy State Energy Commissions

teams. For example, sites with limited water supplies may have regulations covering all possible aspects of water use and water quality protection as opposed to sites with overabundant water supplies whose regulatory agencies are enforcing only basic pollution control measures.

B. COMMUNITY/REGIONAL SUPPORT

Solar thermal-electric power plants will of necessity interact closely with the communities they serve. The electricity they generate must be integrated into the distribution system of the local utility and be available during times of peak demand to be of greatest value. The plants must comply with local regulatory requirements and will require services such as water, sewer, and telephone. They may require manpower and materials for site preparation, construction, and operation, and may need to share transportation facilities with local citizens.

Because of the diversity of these interactions, it is very important that local public opinion be in favor of solar thermal power plant development. Public opinion has a strong influence on government and regulatory agencies. It can either delay or accelerate regulatory processes, and can cause publicity to be either positive or negative. Public opinion is important to all prospective solar thermal-electric power plants but may be of even greater importance to the first engineering experiment because of the various functions it must perform.

All solar energy technology is novel and occupies a prominent position in the public eye. Concurrently, it must prove itself through research, development, and experimentation. The first solar thermal-electric experimental power plants are primarily intended to provide the developers of solar thermal-electric technology with important performance data that will be utilized to improve plant performance. It may take several years for the plants to attain acceptable efficiency. In the interim, plant performance is open to public scrutiny, which could lead to adverse publicity. This may injure development programs, preventing the required research to achieve maximum efficiency. Therefore, a site within a community positively inclined toward plant development or with a need for the type of generating capability a solar thermal power plant can provide may prove to be a more beneficial site than one in a community without this inclination or need.

While adverse publicity is clearly a disadvantage, the lack of public information concerning solar thermal-electric technology may also hinder its development. A third function of the first experimental solar thermal-electric power plants is to demonstrate and publicize the technology and its possible applications to those who may have a need for an electrical generating plant of this type and an interest in utilizing it. An extremely remote site with a dearth of communication media, such as newspapers, newsletters, radio or television coverage, may not perform this publicity function as well as a site with access to these facilities. Convenient access may also be an important aspect in community integration. As in the saying, "a picture is worth a thousand words," public inspection may do more to popularize solar thermal-electric power than many other aspects of the plant.

Other important site conditions relating to community relationships are the community's capabilities to support solar thermal-electric power plants, their stability, experience, and innovation. Close interaction between solar thermal power plants and the communities they serve has advantages and disadvantages to plant development. Close interaction may maximize both the plant's utility to the community and plant operating efficiency by ensuring power is delivered when needed, services required by the plant are provided steadily, and adverse plant impacts on the community are minimized. Disadvantages may result from close interaction if the community is unable to provide the support solar thermal power plants require.

Communities with experience managing and regulating development projects may be better equipped to interface with solar thermal power plants than communities without this experience. They have dealt with regulatory agencies and officials, are familiar with the procedures and time scales involved, have existing management procedures for large development projects and management personnel familiar with them. However, also of importance are the flexibility of management procedures and the diversity of development projects the community has encountered. Management procedures developed for specific types of development, although well understood by all community management personnel, may not facilitate the management of new development projects. A highly specified and structured management procedure may even hinder the management of new development types by trying to force management procedures to fit development projects they were not designed to encompass.

Therefore, it is desirable that the community is experienced in developing innovative management procedures for a variety of development types.

C. UTILITY INTERFACE

It is important to obtain operational experience in a realistic utility environment. Several of the objectives for the first engineering experiment relate to the interfaces of the experimental solar thermal power plant with the local utility grid. Measurements during experimental operation will include utility grid parameters as well as power plant and environmental characteristics. The extent of operational flexibility of the utility grid is also of value for experimental operation of the solar plant.

The application for the first engineering experiment has been defined as a utility/small community with an electrical load of less than 100 MWe, preferably served by a single substation. The load restriction assures that operation of the 1-MWe experimental plant will have a measurable effect on utility grid parameters. It is also important that the plant site is located near the substation and convenient to a transmission line tie-in, and not isolated from the utility grid. Important grid parameters are the real and reactive load seen by the substation and the line reactance between the substation and the plant site.

To maximize the benefit of solar energy usage, it is desirable that a reasonable match exists between the substation demand curve and the available insolation. Since most sites will have a greater amount of insolation during the summer months, a summer peak demand is desirable. It is also desirable that the daily peak occur during the solar day.

VI. SOLAR THERMAL POWER PLANT IMPACT

Previous sections of this report have discussed site attributes from the perspective of their acceptability to solar thermal power plant development. In this section, solar thermal power plant activities will be discussed from the perspective of possible impacts on their sites. A site may be considered inadequate for solar thermal development if the plant's impacts are significant and cannot be mitigated. Solar energy systems impact the environment less than any of the conventional electricity generating technologies. However, as a new technology, there may be impacts which have not yet been identified. As solar thermal technology is developed, it will be important to identify any and every environmental impact and determine its significance to continue its "good neighbor" reputation.

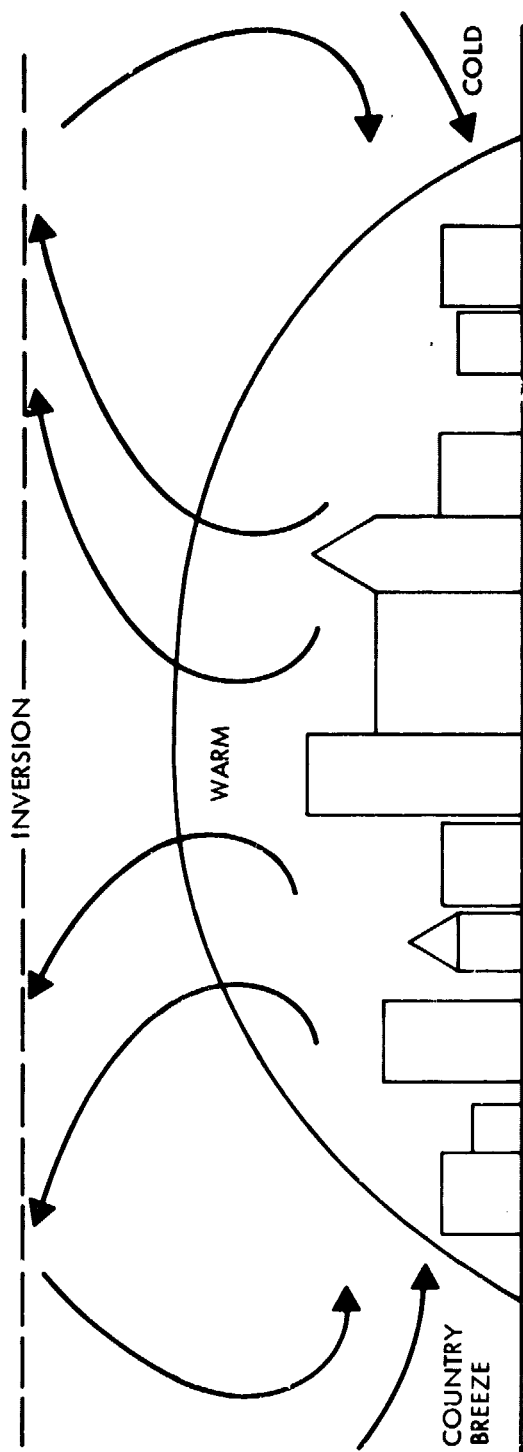
A. MICROCLIMATE

The primary resource that solar thermal power plants require to operate is sunlight or insolation. Insolation is utilized as fuel, and, unlike the fuels utilized by conventional electricity generating power plants, no mining is required, no waste products are produced, no air contaminants are released, and no transportation problems result from its use. These are the major impacts of fossil-fueled and nuclear power plants. In comparison, solar thermal-electric power plants seem to have few impacts that can be directly attributed to their fuel source.

Change of an area's solar radiation budget should be considered as a potential impact peculiar to solar thermal power plants. This could result from the concentration and collection of a large amount of sunlight in an area instead of allowing it to be dispersed naturally. A change in the radiation budget may influence the microclimate of an area, which may be an important impact. Solar radiation drives all climatological systems. Therefore, an alteration of insolation may result in an alteration of climatological conditions. Presently, investigations are being performed to determine the degree that climatological conditions may be impacted by changes in the radiation budget due to solar thermal power plants. Plant size is expected to be an important factor in the degree of this impact; the smaller the plant, the smaller the impact. The impact of a 1-MWe solar power plant with regard to radiation budget and climatological changes is expected to be insignificant.

Changes in solar radiation and heat balance from man's activities are not unknown. Cities reflect and absorb sunlight from pavement, buildings, and windows, and add an enormous amount of thermal energy to the environment (see Figure 9). Climatological changes due to these activities do not seem to be significant. However, solar thermal power plants may impact the radiation budget more directly than cities and may have impacts of greater magnitudes due to widespread use of the technology in the future.

Local climatology may also be influenced by cooling equipment. The type of cooling equipment and ambient temperature together dictate the size and height above ground of vapor plumes, the severity of ground



AIR FLOW AT NIGHT WITHIN AN URBAN ISLAND. DENSE COLD AIR FROM THE SURROUNDING COUNTRYSIDE FLOWS INWARD TO REPLACE RISING, OUTSPREADING WARM AIR.

Figure 9. Man's Influence on the Heat Balance (Ref. 10)

fog, which may block insolation, icing and augmentation of rain and snow (Ref. 6). However, these impacts would occur in any industry utilizing a cooling technology.

Other aspects of solar power plants will impact ecology, including:

- (1) Construction impacts (on site)
- (2) Operation impacts (on site)
- (3) Meteorological impacts (regional)

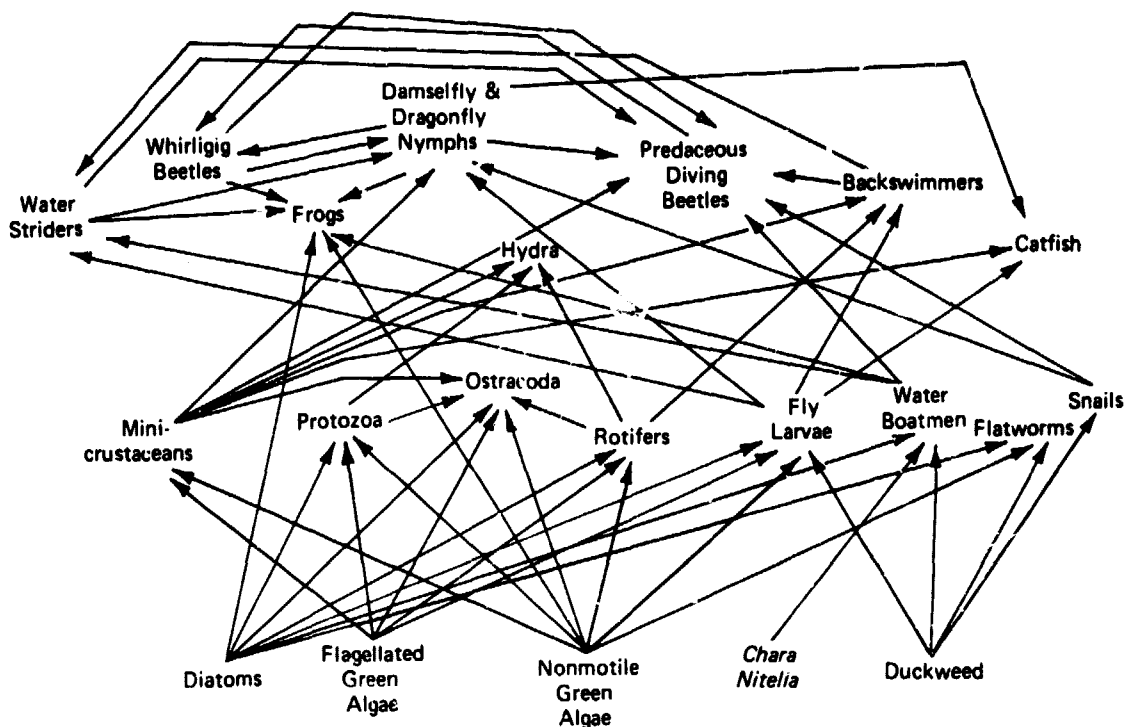
Every development project disrupts the flora and fauna on and around its site. The degree to which this disruption is significant depends on the rarity of the species, and whether the site has been previously disturbed.

The ecological systems in which all organisms live may be thought of as webs where each segment is vital to the survival of the whole (see Figure 10). If a solar power plant were constructed on a site, destroying a segment of the ecological system, the repercussions of this act may adversely impact the ecology in an area many times greater than the site itself. However, ecological systems, because of their web-like interdependence are usually not impacted so significantly that an entire system fails from construction activities on sites of approximately 10 acres, unless the ecosystem is very small or extremely fragile.

Prior to final site selection, the species present on prospective sites and their relationships must be identified. Some species of plants and animals are protected because they are rare. These species are listed on federal and state endangered species lists. Collection of ecological data should include all species on the proposed site and in the immediate area which are included on these lists and any species in the area which have been nominated for inclusion. A site containing endangered species could not be utilized for solar thermal development unless major steps are taken to protect them.

Once construction is complete and the plant is operating, there may be additional ecological impacts. The plant subsystems including cooling will increase shading and require washing which may encourage different types of vegetation than those existing previously to grow. This may in turn attract new species of animals and birds and the intrusion of new species into an area can significantly impact present ecology. It is expected that the growth of vegetation between collectors will be fairly carefully controlled, thus, reducing the significance of this impact. Additionally, chemical solvents may be used to clean collector surfaces which may poison some species. The on-site vegetation, already heavily impacted by construction of the plant, may not constitute a significant impact in this regard. There may not be any on-site vegetation once the plant is complete.

(a) Food Web (Ref. 11)



(b) Energy Flow (Ref. 12)

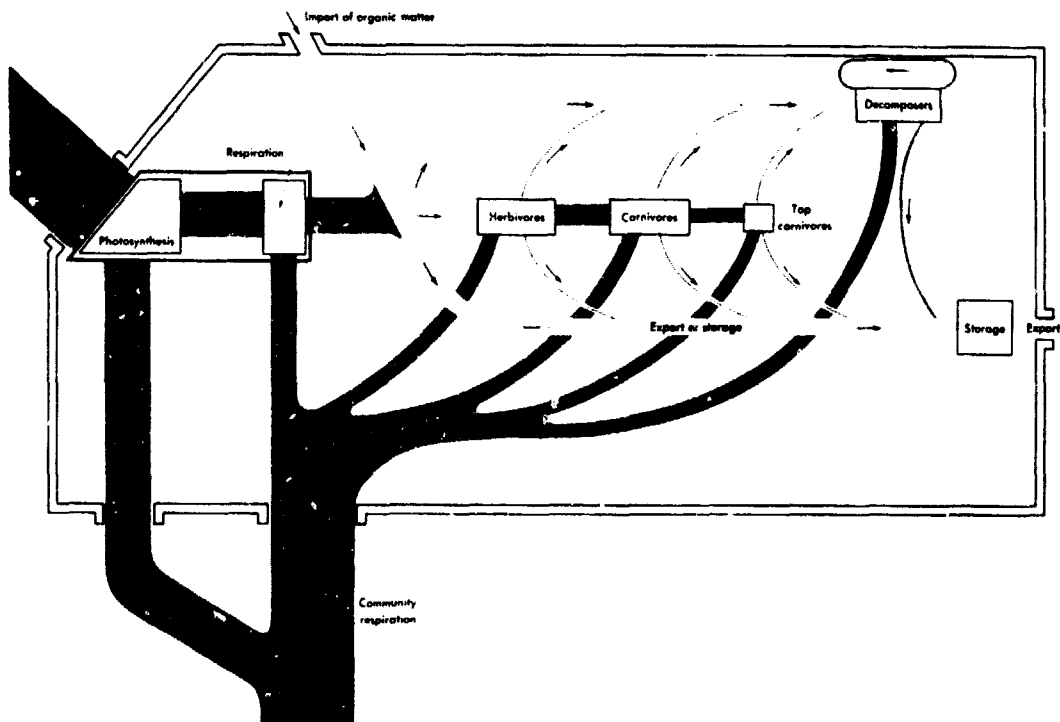


Figure 10. Examples of Ecologic Systems or Food Webs

B. WATER USE

To coordinate a solar power plant's water use with that of the community, the use patterns of the surrounding area should be ascertained. Regardless of the source, natural hydrology (rivers, lakes, and aquifers) or municipal water supplies, it must be determined that water use in the plant should not overburden the existing local water system and that plant water requirements will be satisfied even in times of drought. To some extent water use is dependent on the type of community. Agriculturally based communities have seasonal water use patterns, while industrial, commercial, and residential communities have daily peaks. Each of these users may also require water of different qualities.

Water use compatibility between solar plants and communities is also dependent on the specific uses of the water. The introduction of harmful chemicals into a water system by solar plant activities may not be allowed by local water agencies. Water treatment facilities and water quality regulations vary from site to site. Some communities have minimal treatment facilities and regulations while others have very sophisticated treatment facilities and stringent regulations. Usually, sophisticated equipment and regulations are found in areas with limited water supplies. In these areas water treatment of some kind is a requirement prior to return to the reservoirs. It will either be treated by the user or in a community waste water treatment facility. Solar thermal power plants must coordinate their disposal of waste water with the local regulatory agencies in all areas but particularly in the areas where water is in limited supply.

If the natural hydrology is the source for water uses in the area, great care must be taken by solar power plants to prevent depletion of the resource, lowering of water quality, or alteration of hydrologic systems that may adversely impact the natural environment as well as other water users. Local regulatory agencies influence the configuration of water use and disposal to such a degree that solar thermal power plants must coordinate with them from a very early stage in site selection. Compliance with these agency regulations ensures more than any other single measure that the plant is compatible with an area's established water use patterns because their regulations take into account the quantities and qualities of water available in local sources, the peaks of use, and environmental protection.

C. LAND USE

The primary impact of land used for solar thermal-electric power plants is compatibility and competition with existing and planned land uses for the sites themselves and for right-of-ways for access roads. A solar plant that is compatible with or well integrated into a community's existing land use patterns will serve the community and achieve success much sooner than plants which are not.

Successful integration into an area's land use patterns can be achieved in several ways. One way is to follow zoning ordinances and land use trends. Most communities have land use plans in which specific land uses are designated in specific areas or zones. In California

municipalities are also required to develop General Plans to shape their future growth. Included in General Plans are land use elements that attempt to direct the physical growth of municipal areas to maximize their aesthetics as well as their economics. Solar thermal power plants must comply with General Plans, in cities and counties that have them.

Zoning ordinances must be followed also. Land uses not in compliance with zoning must acquire a change of zoning prior to construction. This can be a lengthy process in which animosity may be generated toward the new development. However, some sites may be so favorable to solar thermal power plant use in all other respects that it may be worthwhile to acquire a zoning change if the site is not appropriately zoned. Other reasons for complying with local zoning are to ensure the availability of adequate support services, like water supply, to prevent adjacent activities from interfering with plants and to prevent adverse plant impacts on them. Areas zoned for like activities are more likely to provide these advantages than areas in which many different development types exist. Compliance with local zoning or planning agencies may facilitate solar thermal power plant integration into a community immeasurably. As in the case described for water use, compliance with these local agencies ensures developers of a clear right to develop solar power plants in an area and guards against delays due to unforeseen regulatory requirements.

D. COMMUNITY

Power plant construction, operation, and maintenance activities may have significant impacts on the community. The degree to which these activities may impact communities is dependent on the type of community and whether manpower, equipment, and materials will be obtained from within the community or whether they will be imported from surrounding areas. A community with a work force possessing appropriate skills, adequate quantities and qualities of materials and equipment for solar power plant development will be least impacted by solar thermal power plant activities. They are more likely to be impacted favorably, if impacted at all, because of increased business from plant activities. Because the workers are in residence, city services are already accommodating them and do not require expansion to maintain adequate service.

A community without these resources may be impacted significantly. The importation of people, materials, and equipment will create more traffic, add to the demand on the water supply and sewage treatment facilities, make additional demands on electric utilities, and may drive plant costs up. If plant employees move their families into the area, schools, fire and police protection, and housing may also be strained. The significance of these impacts vary with the size of the community, the distance between the solar power plant site and the community, and the willingness and capability of the community to meet solar thermal power plant requirements.

E. SAFETY

Safety is another issue in which solar thermal power plants will impact their surroundings. Actually, there are two types of safety

issues: the safety of operational and construction personnel, and the safety of the general public during construction and operation phases. It is assumed in this report that the safety of construction and operational personnel will be similar at all plants regardless of site location. If a site presents development obstacles significant enough to constitute unusual safety hazards to operation and construction personnel, it is a site which probably has other serious impediments to solar thermal power plant development. Assuming a site of this nature would not be chosen, the remaining safety issue is safety to the general public.

During plant construction, the safety of the general public would be threatened in ways similar to the construction of a fossil-fueled generating power plant, however, on a smaller scale. It is during the operation of solar thermal-electric power plants that some safety issues arise which are unique to solar plants. The first issue to be discussed is concerned with the consequences of a solar collector focusing sunlight on people, buildings or other objects outside plant boundaries.

A typical parabolic concentrator in a distributor receiver system has a focal distance of approximately 6 m (20 ft) and concentrates effectively only when pointed at the sun. Hence, there should be no safety hazard due to improper alignment. However, the heliostats in a central receiver system may have focal distances of several hundred feet. The reflected sunlight from a single heliostat is only slightly concentrated, but eye damage is a potential hazard at the focal point of a misaligned heliostat.

To alleviate concern over this issue, sites for central receiver plants may require guarded buffer zones. More study is required on the potential hazard within the field area. There is also a secondary focal point at a greater distance from a heliostat or concentrator. However, intensity at the secondary focus is much reduced, similar to the glare reflected from glassy surfaces.

At certain angles the heliostats of a central receiver plant may reflect light or glare, which may distract or temporarily blind operators of automobiles and aircraft in extreme cases, causing them to lose control. However, glare from solar thermal power plants has not been studied in enough depth to be sure how strong the glare might be, at what angles and distances it is disrupting, and exactly how disrupting it really is. This indicates that central receiver solar thermal power plants with a glare hazard should not be sited adjacent to freeways or airports unless there are mitigating factors that eliminate the glare uncertainty. Glare may also have impacts unrelated to safety. For aesthetic or nuisance reasons, glare may be an unwanted impact of solar thermal-electric plants in close proximity to communities.

The safety of the general public may also be threatened by toxic chemicals if any are used as transport fluids. All liquid waste disposal will be regulated by water quality control boards to ensure environmental and public health protection; therefore, safety hazards from these chemicals would only result from accidents or pipe leaks. The degree of threat posed by toxic plant chemical accidents depends on the specific

chemicals used and the processes within the plant in which they are used. As a siting criterion, the probable pathways of inadvertent toxic chemical releases should be analyzed at each prospective site, both airborne and waterborne.

Water pollution control regulations prevent the disposal of contaminated water outside plant boundaries. If these regulations are complied with, there should be no impact on the ecology outside plant boundaries due to cleaning solvents. However, accidental releases and pipeline leaks must not be discounted.

VII. SITING ISSUE SUMMARY

The siting issues identified in this report are summarized in Table 4. They have been grouped into four major categories: system resources, physical environment, social/institutional, and plant impact. The most important siting issues are asterisked. The following discussion contains brief comments on the significant issues.

A. SYSTEM RESOURCES

The availability of insolation and water is the most important system resource issue. The availability of land is considered to be more of a requirement than a siting issue, especially for the first engineering experiment. However, the suitability of the land available is an important siting issue for the first engineering experiment and will be even more important in the siting of future solar thermal plants. The availability of construction materials and manpower is not expected to represent a significant portion of total plant costs and, therefore, is not considered an important issue.

Solar energy, or insolation, is the most obvious resource requirement for any solar technology, and solar thermal electric technology can utilize only the direct component of the total insolation reaching the earth. The average annual level of direct insolation determines the overall magnitude of this resource, but its consistency and the correlation between insolation availability and energy demand are more important factors in determining the value of the solar resource. The availability and cost of conventional generation alternatives also affects the value of insolation by increasing the need for an alternate energy source.

Water is often overlooked as a resource requirement but its availability and quality can have a major impact on plant costs. Cooling water for energy conversion subsystems is the largest potential water use, but water is also required for many other aspects of plant operation. If unavailable locally in sufficient quantities and qualities, additional engineering will be required to either supply the plant with the kind of water it needs or redesign the plant to utilize locally available water resources. These additional design requirements can increase costs and may reduce operating efficiency.

B. PHYSICAL ENVIRONMENT

Solar thermal power plants are sensitive to environment forces beyond the requirement for insolation. Their most sensitive components are concentrators because they are designed to be lightweight, low-cost structures.

The most potentially damaging environmental force, and therefore the most important, is wind. High winds can cause structural damage and wind borne abrasive material can degrade mirror surfaces. Moderate winds can lower performance by offsetting concentrator alignment. A

Table 4. Siting Issue Summary

<u>SYSTEM RESOURCES</u>	
*Insolation	Intensity and occurrence/time of direct component Measurement capability and/or data availability
*Water	Quantity available Quality
Construction Materials and Manpower	Local availability
*Land	Adjacent land uses Stability Slope Site preparation
<u>PHYSICAL ENVIRONMENT</u>	
*Wind	Velocity and occurrence/time Particulate content Averages and extremes
Precipitation	Types Averages and extremes Erosion and flood occurrence
Temperature and Air Quality	Averages and extremes Degree change/time
<u>SOCIAL/INSTITUTIONAL ENVIRONMENT</u>	
*Legal-Regulatory	Regulation complexity Regulatory impediments Capability of local regulatory agencies Proposal team/regulatory agency rapport
*Community/Regional Support	Public opinion Publicity Access Resources Stability Experience and innovation
*Utility Interface	Grid flexibility Convenient transmission line tie-in
<u>SOLAR THERMAL POWER PLANT IMPACT</u>	
Microclimate	Albedo changes Meteorological change
*Water Use	Compatibility Depletion Other users
*Land Use	Compatibility Zoning Right-of-way
Ecology	Endangered species Exotic species intrusion Critical link
Community	City services strained Nuisance Aesthetic
Safety	Malfunctioning tracking mechanisms Nuisance Glare hazard Toxic chemical leaks High-temperature pipelines

typical concentrator design allows concentrators to operate at full performance in winds up to 14 m/s (31 mph), at reduced performance in winds up to 25 m/s (55 mph) and to survive without damage, in a stowed position, winds up to 40 m/s (90 mph) (Ref. 7).

C. SOCIAL/INSTITUTIONAL ENVIRONMENT

Another aspect of the environment to which solar thermal plants are sensitive is the social/institutional structure. This is especially true for the first engineering experiment because of the goal to both provide experimental data and publicize the technology. The legal-regulatory aspects are important to prevent legal entanglements and regulatory delays. To avoid these snags, these requirements must be understood and coordinated from the earliest phases in project development. The community/regional support aspect is important to plant success in both the physical and social senses. Community support with regard to the provision of plant resources and with regard to acceptance and positive publicity is both very important.

D. PLANT IMPACT

Any new technology development will impact the area in which it is applied. This will also be true for solar thermal power plants. Since solar thermal technology is relatively new, not all of the potential impacts have been fully investigated. At this point the impacts on water and land use are the most significant. Water use has an important impact because many areas with good insolation lack a significant quantity of water. Water use regulations are very complex, especially in arid regions. Land use is important because greater areas are required relative to conventional generation technologies, and because competition for land is increasing.

In relation to conventional electricity generation technologies, solar thermal-electric systems have negligible environmental impacts. Although a small amount of environment degradation is unavoidable, future environmental quality will be improved by the displacement of conventional electricity generation facilities with solar thermal-electric plants.

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